Reformate images in lung cancer: Are axial images enough in preoperative evaluation?

Reformate images in lung cancer

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Abstract

Aim: The T descriptor not only reflects a potentially different prognosis but may also change treatment. Unfortunately, due to workload and time constraints, many clinicians only evaluate axial plans preoperatively. Since the longest tumor axis is not always aligned with the axial, we assessed the longest measured dimension of the entire tumor on reconstructed computed tomography (CT) in the lung window setting.

Methods: The study included 57 out of 99 consecutive patients who underwent complete resection due to lung cancer between January 2008 and December 2012. Forty-two patients were excluded as the inoperable, and lesion was regressed after adjuvant chemotherapy. During the three years of follow-up, ten cases died.

Results: In the comparison differences between the tumor diameter in CT (p=0.02), the pathological tumor diameter (p=0.003) were found statistically significant. Localization was evaluated as incorrect in four cases. Other planes gave the most accurate results in determining the localization. In the best way, fissure invasion was detected in the sagittal plane, while the pleural invasion was discovered in the coronal plane but missed on axial. As for the lesion size was 8% more than the axial, and this difference was less in the others. Although axial is significantly different from other groups (p<0.01); because of this, the stage of only two patients changed.

Discussion: Reformat imaging provided more information about the tumor and hence the prognosis. Mainly, Thoracic wall, pleural invasions in centers without Magnetic Resonance Imaging or patients it cannot be used alternatively, and fissures were determined more precisely.

Keywords

Reformate images; Lung cancer; Staging

Introduction

In the lung cancer staging, the TNM system is used; (T) is used for tumor, (N) for the nodal spread, and (M) for distant metastasis. Computed tomography (CT) plays an essential role in the diagnosis and staging of lung cancer [1]. Thanks to the multidetector devices and spiral scanning technique, and the cross-sectional thickness decreases by 0.5 mm, multiplanar reconstructions can now be performed retrospectively [2]. The T descriptor provides information on tumor size, location, and invasion of adjacent structures such as pleura, mediastinum and bone, and the presence of additional nodules (s) in the same lobe (T3) or the same lung (T4). The size of the primary tumor not only reflects a potentially different prognosis but may also change treatment [1-3]. Unfortunately, due to workload and time constraints, many clinicians only evaluate axial plans. When only axial sections are evaluated preoperatively, the largest size of the lesion, the presence of invasions such as brachial plexus and pleura, and even the localization of the lesion may provide false information. Since the longest tumor axis is not always aligned with the axial, coronal, or sagittal planes, we evaluated the longest measured dimension of the entire tumor on reconstructed CT images in the lung window setting.

Material and Methods

The study includes a retrospective analysis of patients who had been diagnosed and operated in our hospital. Patients included in the retrospective study were accepted from the lung cancer database collected for another retrospective study. All procedures performed in studies involving human participants were following the ethical standards of the institutional and/ or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Written informed consent was not obtained from patients due to the retrospective nature of this study. Ethics committee approval was received for this study from the ethics committee of the local University (2016/477). All patients were staged with seventh TNM classification, which was published in 2009. Follow-up data were completed in January 2016. A total of 99 consecutive patients with lung cancer were included in the study. Three patients were excluded from the study as the lesion was regressed after adjuvant chemotherapy. Additionally, 39 patients were excluded because they were inoperable.

CT protocol and image analysis

Entire thorax CT scans were done with one of the undermentioned two scanners: Siemens SOMATOM Emotion 6 CT Scanner and SOMATOM Sensation 64, (Siemens Medical Solutions, Erlangen, Germany). Views have obtained the starting from the apex to the adrenal glands during breath-holding at the end of inspiration with a helical technique. CT parameters included tube voltage, 80–140 kVp; tube current, 28–580 mA; and slice thickness, 0.1–2 mm. Scans were reformatted at 0.1–2 mm intervals on the workstation. All views were uploaded to SureView™ Multislice Spiral Image Reconstruction (Siemens Medical Solutions, Erlangen, Germany). After the names of the patients were hidden, each series image was given a number. The images were re-evaluated in the lung window settings (width, 1500 Hounsfield units (HU); level, –500 HU) by a radiologist with ten years of experience who did not know the results of surgery and

pathology of those patients. Each tumor was reconstructed in the axial, sagittal, and coronal planes, respectively. Localization and the maximum tumor diameter were carefully measured using the electronic caliper and recorded at each plane.

Statistical analysis

These results were compared with the surgery notes and pathologic findings. Statistical analysis was performed with SPSS Version 21.0 statistic software package (SPSS Inc. Chicago, Illinois, USA); ANOVA test was used for comparing the dimensions. Descriptive statistics for quantitative data such as mean, maximum, and minimum values were computed. The level of statistical significance was considered as $p < 0.05$.

Findings

The study included 57 patients who underwent complete resection in our clinic between January 2008 and December 2012 in our clinic. Of the patients whose mean ages were 60.2 (40-80) years, 50 (87.7%) were male, and 7 (12.3 %) were female. Patients were called every two weeks for the first three months and then every two months for a follow-up visit. All patients were followed for three years. Ten cases (17.5%) died in the first three years. The causes of two deaths were respiratory failures (3.5%), one myocardial infarction (3.5%), four organ failure (7%), and three pneumonia and sepsis (5.3%), respectively. Nine patients developed local metastasis (15.7%), and seven (12.2%) distant metastasis. Forty-seven patients (82.4%) completed the follow-up. In the comparison differences between the tumor diameter in CT (p=0.02), the pathological tumor diameter (p=0.003) were found statistically significant.

In four cases, lesion localization was evaluated as incorrect only in the evaluation of axial images. Although two of the four incorrectly localized lesions were reported as the middle lobe, the lesions were in the upper lobe anterior segment. The other mislocalized two lesions were also between the left lung inferior lobe superior segment and the apicoposterior segment. It was found that sagittal and coronal reformatted images gave the most accurate results in determining lesion localization. The sagittal plane images best-detected fissure invasion; 4 cases pleural invasion was missed on axial evaluation. Pleural invasion of the upper lobe lesions was best identified with coronal assessment (pleural lesion was identified by coronal plane but missed on axial).

As for the evaluation of lesion size, it was seen that the lesion size was 8% more than the axial plan images, and this difference was less in the sagittal and coronal plane. Although axial plane images are significantly different from other groups (p<0.01), because of this difference, the TNM stage of only two patients changed.

In the longest dimension measurement, reformat image was created in many plans, and the longest dimension was determined. Patients with lobe atelectasis were not included in the study because the longest dimension could not be detected.

Results

The fissures were revealed sharpest in the sagittal images (Figure 1). The lesion was located close to the fissure in 20 patients. In 4 patients, the mass was found in a different lobe other than the one indicated on the axial images. The upper lobe anterior lesion in the right lung was defined as the middle
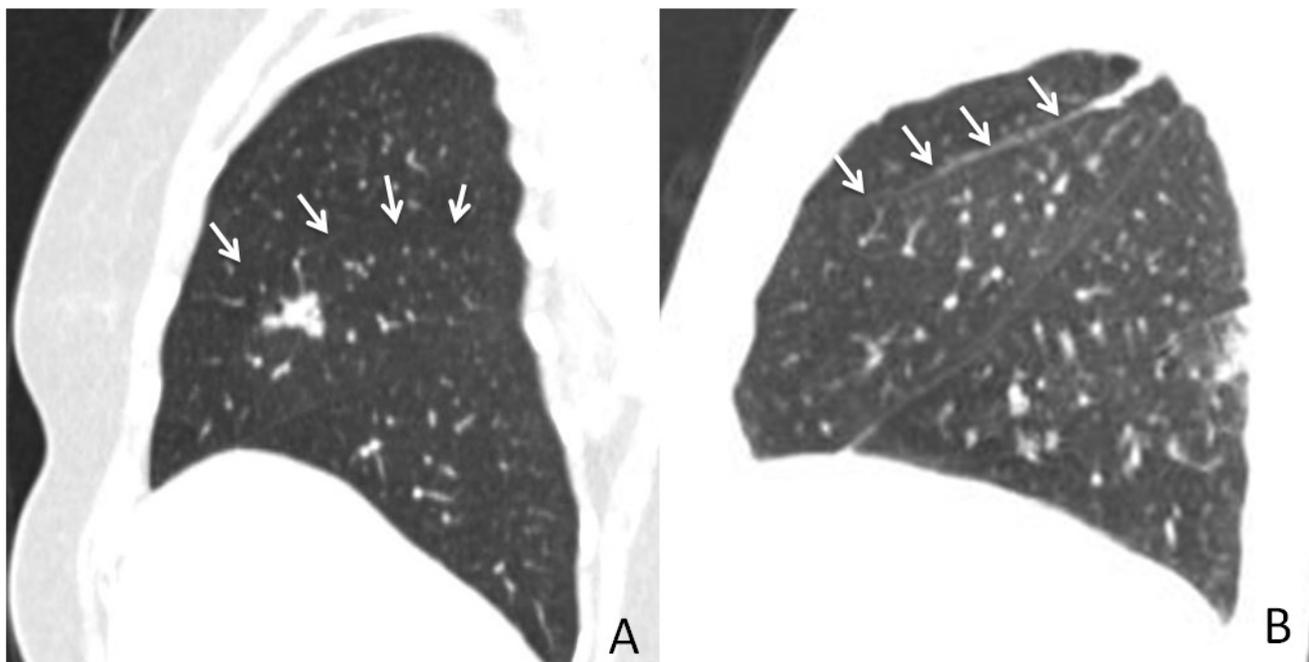
Figure 1. In the picture on the right, the minor fissure cannot be viewed because it is horizontal. In another patient on the left, as the upper lobe volume was small (due to bronchiectasis), the fissures are longitudinal. Minor fissures that cannot be observed in the axial plane are more clearly seen in sagittal sections. Sagittal plane reconstructed images of different patients. (A) Variations of the minor fissure (arrows) that cause mistakes in evaluation. The minor transverse fissure is not easy to detect on the axial plane. (B) The too high position of minor fissure also leads to errors.

Figure 2. Two different lesions in two different patients, both in the same localization in the axial plane. The lesion on the right (A) was in the middle lobe and invaded the upper lobe. The other lesion (B) has fissure contact at the lower lobe superior but does not invade the fissure in surgery. Both lesions were mislocalized in the axial plane.
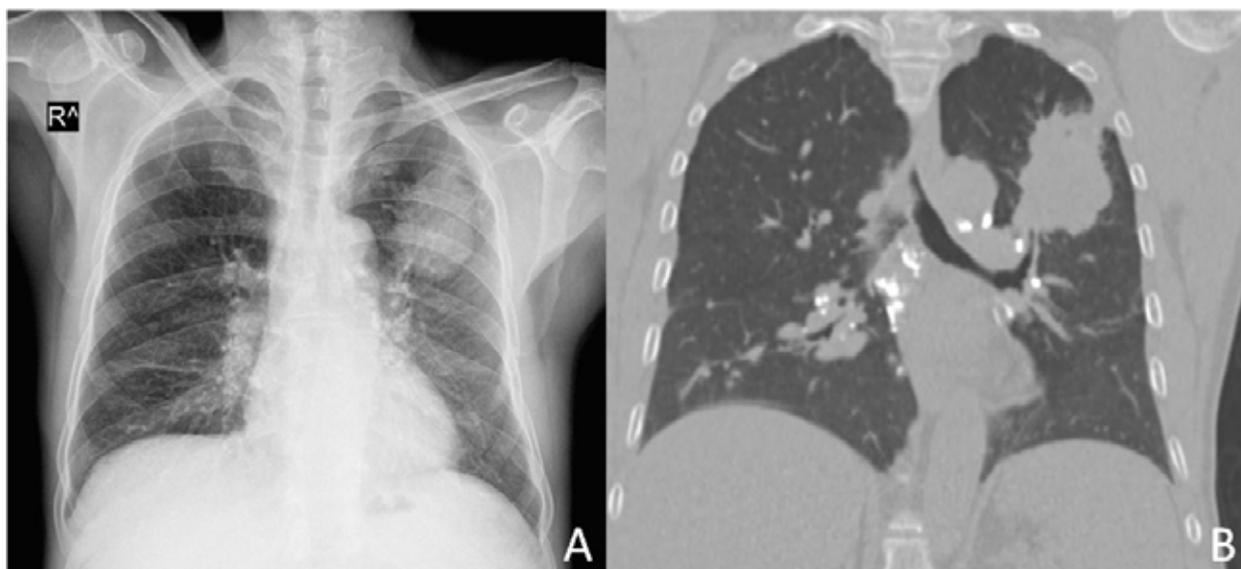
Figure 3. Coronal reformat length of the patient, which was accepted as T2 according to axial diameter (6.2 cm), was measured as 7.2 cm, and the stage was corrected as T3 in the case whose PA chest X-ray and coronal reformat images were shown.

Table 1. Relatively the most accurate research plane

Researched Plane	Accuracy of Lobar Localization (%)		Accuracy of Fissure Invasion (%)		Accuracy of Upper Lobe Lesion's Pleural Invasion (%)
	Fissure Close Lesions	Percentage	Fissure Close Lesions	Percentage	
Axial	80 (16/20)	92,9 (52/57)	80 (16/20)	92,9(52/57)	80 (8/10)
Coronal	95 (19/20)	98 (55/57)	90 (18/20)	96,4(54/57)	100 (10/10)*
Sagittal	100(20/20)*	100(57/57)*	95(19/20)*	98(55/57) *	90 (9/10)

Table 2. Survival rate (%) in two and five years due to the Clinical and Pathologic Stages eighth TNM Classification of Lung Cancer. Adopted from Goldstraw P, Chansky K, Crowley J, et al. The IASLC Lung Cancer Staging Project: proposals for the revision of the stage grouping in the forthcoming (eighth) edition of the TNM classification of lung cancer. J Thorac Oncol. 2016;11:39-51.
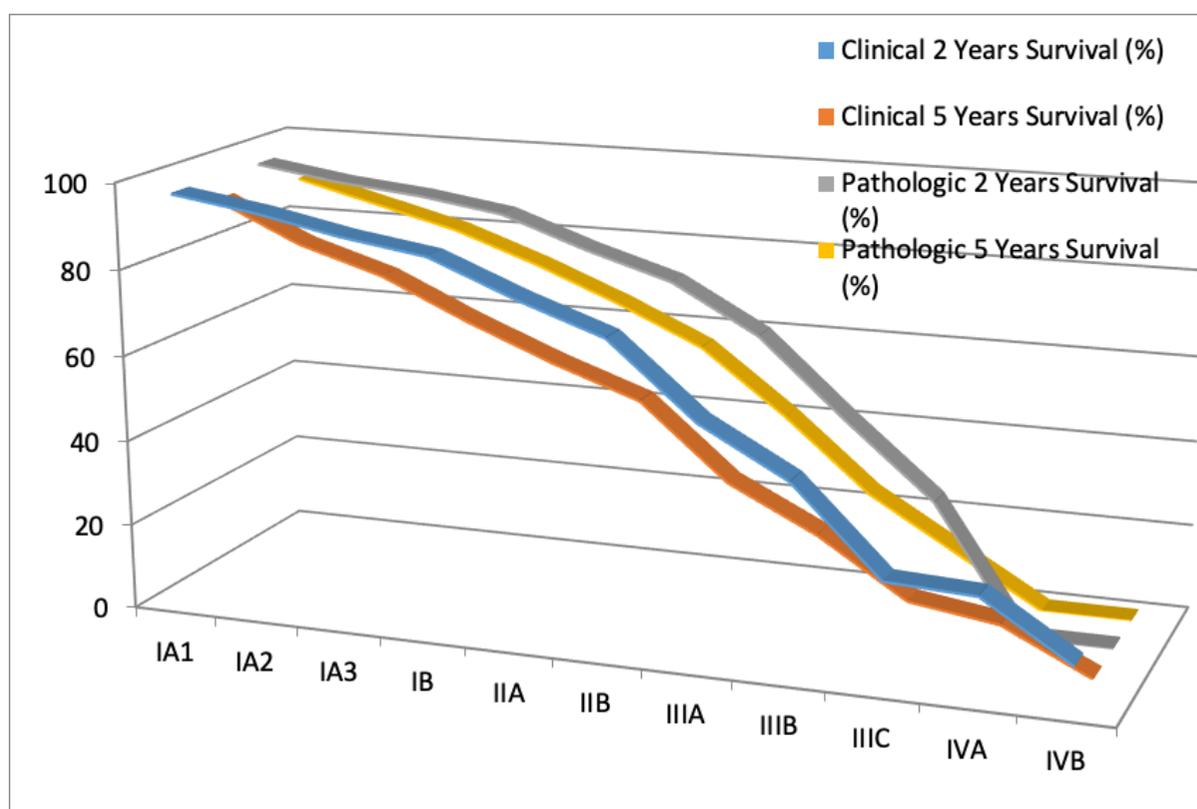
lobe in 2 patients, while the superior lesion in the left lobe was defined as the apicoposterior segment of the upper lobe in 2 patients. In particular, sagittal reformat images of all patients determined the lesion segment correctly (Figure 2). The axial, coronal and sagittal image accuracy rates were 80%, 95%, and 100%, respectively compared to fissure lesions, and 92.9%, 98%, and 100%, for all lesions (Table 1).

Fissure invasion was evaluated separately in each plan. Fissure invasion was detected most accurately in sagittal images (95% accuracy). The pleural invasion could not be detected in axial images in 4 patients (80% accuracy).

The pleural invasion was detected more accurately in coronal reformat images in upper lobe lesions. The parietal pleural invasion was discovered in the coronal image in 2 patients with close to pleural lesions in 10 upper lobes, but axial evaluation could not be performed. The invasion of a lesion extending to the mediastinal pleura in the sagittal plane could not be evaluated.

The longest size of the lesion showed an average 8% increase in reformat images compared to the axial plan. However, this increased size extended the stage only in 2 patients (Figure 3).

Discussion

Even when the incidence of lung cancer in the United States is decreasing, 226.160 new cases corresponding to 14% of all new cancer diagnoses are detected annually. Despite improved diagnostic and therapeutic options, 5-year overall survival is 16% in all stages. In spite of such high incidence and low survival, cancer-related deaths account for 28% of lung cancer. The initial diagnosis of lung cancer is often made by chest radiography or computed tomography (CT). Non-invasive procedures such as CT, magnetic resonance (MR) imaging, and positron emission tomography (PET) / CT examinations, and invasive procedures such as endobronchial ultrasound-guided fine-needle aspiration, transthoracic fine-needle aspiration biopsy, and mediastinoscopy improve the accuracy of clinical staging of non-small cell lung cancer (NSCLC) [3,4]. This original TNM staging system for lung cancer started with 2155 cases at M.D. Anderson Cancer Center in Houston. In 1997, the fifth revision reached 5319 cases. Although it is an impressive database, it had many shortcomings. The first was mainly a single-center database. Second, 968 out of 5319 cases were the ones who were not operated at this center and sent to M.D Anderson for confirmation of stage and histology. Third, although the number of cases was relatively large for that date, the individual subgroups were small. Finally, the majority of patients underwent surgical treatment. Although surgery is an important treatment option, treatment has been expanded with chemotherapy and radiotherapy supplementation in the last quarter-century. In 1996, the International Association for the Study of Lung Cancer (IASLC) transformed into an international database that underpins future revisions. TNM staging; In the next decade, with the development of the database, in 2005, 100.869 cases were reached from 45 different sources in 20 countries. 81.495 of these cases were used for 7th TNM staging. Of the cases, 68.463 were non-small cell lung cancer (NSCLC) cases and 13,032 small cell lung cancer (SCLC) cases. Of the included patients, 41%were treated only with surgery,

23% only with chemotherapy, 11% only with radiation, and the rest with sequential therapy [4].

The T identifier determines the size, location, and relationship of the primary tumor with its surrounding structures. Traditionally, CT is used to evaluate the anatomical extent of the disease and primary tumor, FDG-PET is used to detect nodal and extra-thoracic metastatic disease, and MRI is used to assess tumor spread to the chest wall and brachial plexus. The correct staging of NSCLC is crucial in selecting treatment. In patients with NSCLC, imaging is essential for the clinical-stage; some limitations and pitfalls are specific to each imaging method that may affect staging accuracy. Moreover, infection, inflammation, and FDG-free malignancies are potential hazards, and misinterpretation may alter staging and management [1]. Descriptor T1 and T4 reflect prognosis and determine treatment options in patients without limited nodal metastasis and distant metastasis. Generally, measurements are performed manually in two-dimensional images using electronic calipers without standardized rules for measurements or window settings. In the literature, multidimensional measurements have been investigated as an alternative and mentioned in the current manual. Differences in tumor measurements may change the general stage.

In particular, subsolid and spiculated irregular nodules measurements are often inconsistent, and inter-clinician compliance is low. Therefore, we excluded this group of patients. Although axial tumor sizes are most commonly used, studies have shown that measurements in the coronal and/or sagittal planes may yield different results. In a study; The T phase caused an increase up to half of the cases according to the window setting, and up to a quarter of Multiplanar reformatted. Multiplanar reformatted CT at lung measurement and pathology; It shows an average increase of 7.8 mm in NSCLC. This means that the difference is increased in tumors smaller than 2 cm [5]. In another study, it reported an increase in tumor size in 18-20% [6]. However, this rate was lower in our study than the literature (8%).

Primark et al. [7] stated that the tumor was inoperable in 24% of the 275 patients series before reformat imaging, but these inoperable criteria could not be determined by CT. However, Kuriyama et al. [8] reported that thin-section 3D images showed visceral pleural invasion with 92% accuracy, which was significantly superior to 2D models with only 17% accuracy. In our study, the pleural invasion was detected by reformat imaging in only six patients (10.5%) with an accuracy rate of 80%. Particularly with dynamic MR imaging, local invasion of the chest wall, mediastinum and diaphragm pleura can be determined with a sensitivity of 100% and specificity of 82.9%. The presence or absence of pleural and chest wall invasion of the primary tumor may be significant in patients considered for surgical resection and may change the surgical approach, the degree of resection, and the need for chest wall reconstruction. Tumors invading the visceral pleura had a T2 identifier and a 5-year survival rate of % 58, while tumors with parietal pleural or chest wall involvement were T3 with a survival rate of 31%. Unfortunately, pleural involvement is difficult to assess with CT or MRI, and it is often impossible to distinguish between the invasions of visceral pleura (T2) and limited invasion of parietal

pleura or chest wall (T3). A pleural tumor on CT may not be invasive, even if it is associated with local pleural thickening, and this pitfall may cause an incorrect T identifier definition . The only CT findings that allow reliable diagnosis of pleural and chest wall invasion are rib destruction or the presence of a prominent chest wall mass. A wide-angle of the mass to the pleural surface, more than 3 cm of contact with the pleural surface, and visible pleural thickening associated with the primary mass, 68% sensitivity and specificity were used as chest wall invasion reporting criteria.

Two of the three criteria exist in 66% of the cases. This lack of CT sensitivity and specificity is a limitation in the staging and surgical planning of the patients with primary tumors involving the pleura or chest wall [3]. Thoracic wall and pleural invasion can be performed more clearly on MR images (92% accuracy) [6]. However, when thin sections are provided, coronal reformat images (with an accuracy of 80%) also yield close results. It can be used as an alternative in centers where MRI is not available or cannot be used in patients.

The T3 identifier based on an additional pulmonary nodule (s) in the same lobe and with different lobe (s) may be necessary for determining treatment. These nodules, reported in 16-28% of patients with NSCLC, may be metastases from a primary lung tumor, a second primary NSCLC, or benign nodules. 96% of the nodules that are smaller than 1 cm in diameter are benign. In addition to size, morphological appearances such as smooth edges can be used to determine benign.

However, even up to 21% of nodules with these characteristics are malign. FDG-PET / CT can help distinguish benign and malignant nodules, but this is typically valid for nodules of 7 mm or more due to the spatial resolution of PET / CT. In addition to size limitation, the sensitivity and specificity are 40-80% and 40-100% in the diagnosis of malignancy. If the presence of additional nodules (s) changes the initial treatment plan, histological confirmation may be required. In this regard, if the nodule is in the same lobe, and the chosen treatment is a lobectomy, preoperative diagnosis is essential to determine treatment.

Imaging and staging must be accurate. Another factor that changes the T stage is lesion size. The 2, 3, 5, and 7 cm measurements in the longest dimension of the lesion are the upper threshold values for T1a, T1b, T2, and T3 tumors, respectively [5]. According to the literature, the craniocaudal dimension may be longer, especially in central lesions. Besides, our study showed that the larger size was measured in reformat images. However, in our series of 57 patients who underwent surgery, this difference in size only changed the stage in 2 patients. While there was a statistically significant difference in the mean size, unlike the literature, there were no statistically significant changes in the stage. We believe that this is due to the heterogeneity and relatively limited number of patients in our patient group.

Also, it may cause fissure invasion in the lesions close to oblique fissures or even localization of the lesion. Fissure and localization were determined incorrectly only in 4 patients (7%). The most common error is the distinction between the upper lobe anterior and middle lobe, as well as the upper lobe apicoposterior and lower lobe superior segments. In our study,

it was seen that sagittal reformat images revealed the lesion localization and fissure invasion more accurately by revealing the fissures more clearly.

The 7th TNM Staging System used in our research was used from January 2010 to January 2017. The current 8th Staging system was formed, analyzing the data of approximately 77.000 patients (70.967 non-small cells; 6189 small cells) from 16 countries between 1990 and 2010. It is noteworthy that the changes were concentrated on the ''T and M'' descriptor compared to the previous one and that there was no change in the N factor .

T-classes were rearranged, uniquely as it was determined that prognosis worsened with each centimeter increase in tumor diameter (Table 2). In the seventh staging system, Tumors smaller than 3cm were classified as T1, tumors between 3 and 7cm were classified as T2. In the eighth staging system, tumor sizes up to 5 cm were increased one step in each centimeter and were assigned to five groups: T1a, T1b, T1c, T2a, T2b. Thus, T1, previously examined in two subgroups, was divided into three subgroups.

In the seventh staging system, tumors between 3-5 cm were called T2a, tumors between 5-7 cm were T2b, and tumors larger than 7 cm was named T3. In the new staging system, tumors between 4-5 cm were raised to T2b, tumors between 5-7 cm to T3, and tumors greater than 7 cm to T4.

In the new system, where the visceral pleural invasion was again classified as T2, endobronchial involvement (without carina involvement) less than 2 cm from the carina was reduced from T3 to T2 and diaphragmatic invasion that was found to have a worse prognosis than other T3 lesions was raised to T4 class. Obstructive pneumonia extending into total atelectasis of the hilar region was also classified as T2 (previously T3), unlike the seventh staging system. In the 8th staging system in which mediastinal pleural invasion was excluded, T1a (mi) (minimally invasive adenocarcinoma) was defined for adenocarcinoma and was identified as adenocarcinoma with an invasion of mm 5 mm and tumor size of 5 cm.

In the evaluation of the M factor, no change was required in the M1a group, but when the data of the M1b patients were analyzed, a new group was formed for those patients who had more than one metastasis in one or more organs and had a worse prognosis than patients with single metastasis in an only distant organ. Thus, single non-thoracic metastasis was classified as M1b, and multiple metastases outside the thorax were classified as M1c (various or multiple in one organ or single or multiple in multiple organs) [3, 5, 6].

This study showed the T stage, which changed depending on the combination of reconstructed image planes. The 8th edition proposed the use of multiplanar reconstruction with lung window for TNM staging, clinical T staging, and pathological measurement of fresh specimens after sectioning. Also, our study has been going on.

Like in any work, our study has some limitations. First, the possibility of selection bias is not forgotten due to the study population only includes patients who have undergone surgery and pathological validation. Second; it is a single-center and a tertiary step, relatively limited and low number of patients, and non-gender equality. Nevertheless, it did not affect the

results of the statistical analysis. Third and finally, due to its retrospective nature, CT protocols, and slice thickness was not uniform.

No matter what classification, despite the size and globality of the database, it mainly consists of retrospective data. The data collection process is about the comprehensive review and evaluation of the data of institutions or organizations that are willing and able to participate. In particular, regions such as North America and Japan are overrepresented; on the contrary, regions like Africa are underrepresented. The same is true for non-surgical cases. The amount of detail available from sources is different.

Nonetheless, potential tumor markers were collected less than necessary for a robust analysis of their effects. Generally, large databases lack the level of detail, and smaller databases have limitations imposed by their size. Evaluation using Surveillance, Epidemiology, and End Results database is currently not possible due to a lack of sufficient detail.

Conclusion

Reformat imaging provided more information about the tumor and increased its ability to be prognostic. Especially with sagittal evaluation, fissures and invasions were determined more precisely. It can increase predictability, along with other methods. Thoracic wall and pleural invasion can be used as an alternative in centers without MRI, or in patients; it cannot be used. We propose an approach that combines textural and morphological features to improve malignancy detection [3]. It shows that standard measurement methods accepted and/or will be recognized worldwide are required for correct staging and treatment.

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